Section 5

ARROWTOOTH FLOUNDER

By

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EXECUTIVE SUMMARY

The following changes have been made to this assessment relative to the November 2001 SAFE.

Changes to the input data

1) 2002 survey size composition.
2) 2002 shelf and slope survey biomass point-estimates and standard errors.
3) Estimate of catch and discards through 14, September 2002.
4) Estimate of retained and discarded portion of the 2001 catch.
5) New model software (see September SAFE report).

Assessment results

1) The projected age 1+ total biomass for 2003 is 596,600 t.
2) The projected female spawning biomass for 2003 is 436,400 t.
3) The recommended 2003 ABC is 112,300 t based on an $F_{0.40}$ (0.30) harvest level.
4) The 2003 overfishing level is 139,000 t based on a $F_{0.35}$ (0.38) harvest level.

	2001 Assessment recommendation for 2002 harvest	2002 Assessment recommendation for 2003 harvest
Total biomass	671,200 t	596,600 t
ABC	113,300 t	112,300 t
Overfishing	137,000 t	139,000 t
F_{ABC}	$F_{0.40} = 0.22$	$F_{0.40} = 0.30$
$F_{overfishing}$	$F_{0.35} = 0.27$	$F_{0.30} = 0.38$

INTRODUCTION

The arrowtooth flounder (Atheresthes stomias) is a relatively large flatfish which occupies continental shelf waters almost exclusively until age 4, but at older ages occupies both shelf and slope waters. Two species of Atheresthes occur in the Bering Sea. Arrowtooth flounder and Kamchatka flounder (A. evermanni) are very similar in appearance and are not usually distinguished in the commercial catches. In past years, these species were not consistently separated in trawl survey catches and are combined in this assessment to maintain the comparability of the trawl survey time series. Arrowtooth flounder ranges into the Aleutian Islands region where their abundance is lower than in the eastern Bering Sea. The resource in the EBS and the Aleutians are managed as a single stock although the stock structure has not been studied.

Arrowtooth flounder was managed with Greenland turbot as a species complex until 1985 because of similarities in their life history characteristics, distribution and exploitation. Greenland turbot were the target species of the fisheries whereas arrowtooth flounder were caught as bycatch. Because the stock condition of the two species have differed markedly in recent years, management since 1986 has been by individual species.

Arrowtooth flounder begin to recruit to the continental slope at about age 4. Based on age data from the 1982 U.S.-Japan cooperative survey, recruitment to the slope gradually increases at older ages and reaches a maximum at age 9. However, greater than 50% of age groups 9 and older continue to occupy continental shelf waters. The low proportion of the overall biomass on the slope during the 1988 and 1991 surveys, relative to that of earlier surveys, indicates that the proportion of the population occupying slope waters may vary considerably from year to year depending on the age structure of the population.

CATCH HISTORY

Catch records of arrowtooth flounder and Greenland turbot were combined during the 1960s. The fisheries for Greenland turbot intensified during the 1970s and the bycatch of arrowtooth flounder is assumed to have also increased. In 1974-76, total catches of arrowtooth flounder reached peak levels ranging from 19,000 to 25,000 t (Table 5.1). Catches decreased after implementation of the MFCMA and the resource has remained lightly exploited with catches averaging 12,200 t from 1977-2002. This decline resulted from catch restrictions placed on the fishery for Greenland turbot and phasing out of the foreign fishery in the U.S. EEZ. Total catch reported through 14 September, 2002 is 9,131 t (well below the ABC of 113,000 t). NMFS Regional Office reports indicate that bottom trawling accounted for 91% of the 2002 catch.

Although research has been conducted on their commercial utilization (Greene and Babbitt 1990, Wasson et al. 1992, Porter et al. 1993, Reppond et al. 1993, Cullenberg 1995) and some targetting occurs, arrowtooth flounder currently have a low perceived commercial value as they are captured primarily in pursuit of other high value species and most are discarded.. The catch information in Table 5.1 reports the annual total catch tonnage for the foreign, JV, and DAP fisheries. The proportion of retained and discarded arrowtooth flounder in Bering Sea fisheries can be estimated from observer sampling applied to the 'blend' estimate of reported and observed retained catch as follows:

Year*	Retained	Discarded	Total	% Retained
1985	17 t	72 t	89 t	19
1986	65 t	277 t	342 t	19
1987	75 t	320 t	395 t	19
1988	3,309 t	14,107 t	17,416 t	19
1989	958 t	4,084 t	5,042 t	19
1990	2,356 t	10,042 t	12,398 t	19
1991	3,211 t	18,841 t	22,052 t	15
1992	675 t	9,707 t	10,382 t	7
1993	403 t	6,775 t	7,178 t	6
1994	626 t	13,641 t	14,267 t	4
1995	509 t	8,772 t	9,281 t	5
1996	1,372 t	13,280 t	14,652 t	9
1997	1,029 t	9,024 t	10,054 t	10
1998	2,896 t	12,345 t	15,241 t	19
1999	2,538 t	8,035 t	10,573 t	24
2000	5,124 t	7,805 t	12,929 t	60
2001	4,271 t	6,959 t	11,230 t	62

*1990 % retained rate applied to the 1985-89 reported retained DAP catch.

Substantial amounts of arrowtooth flounder are discarded overboard in the various trawl and longline target fisheries. Largest discard amounts occurred in the Pacific cod, rock sole, 'other flatfish' and Greenland turbot fisheries.

DATA

The data used in this assessment include estimates of total catch, trawl survey biomass estimates and standard error from shelf and slope surveys, sex-specific trawl survey size composition and available fishery length-frequencies from observer sampling .

Fishery Catch and Catch-at-Age

Fishery catch data are available from 1970 - September 14, 2002 and fishery length-frequency data from 1978-91.

Survey CPUE

The relative abundance of arrowtooth flounder increased substantially on the continental shelf from 1982 to 1990 as the CPUE from AFSC surveys on the shelf increased steadily from 1.6 to 9.9 kg/ha (Fig. 5.1). The overall shelf catch rate decreased slightly to 7.1 kg/ha during 1991 but increased to 9.5 kg/ha during the 1992 bottom trawl survey. The CPUE continued to increase through 1996 to 12.0 kg/ha. These increases in CPUE were also observed on the slope from 1981 to 1986 as CPUE from the Japanese land-based fishery increased from 1.5 to 21.0 t/hr (Bakkala and Wilderbuer 1990). The CPUE declined from10.3 kg/ha in 1997 to 5.7 kg/ha in 1999 and has increased since that time to 7.7 kg/ha in 2002.

Absolute Abundance from Trawl Surveys

Biomass estimates (t) for arrowtooth flounder from U.S. and U.S.-Japanese cooperative surveys in the eastern Bering Sea and Aleutian Islands region are as follows:

	Eastern Bering Sea			Aleutian Islands
Year	Shelf	Slope	Shelf and Slope combined	
1975	28,000	--	--	--
1979	35,000	36,700	71,700	--
1980	47,800	--	--	40,400
1981	49,500	34,900	84,400	--
1982	67,400	24,700	92,100	--
1983	149,300	--	--	45,100
1984	182,900	--	--	--
1985	159,900	74,400	234,300	--
1986	232,100	--	--	125,700
1987	290,600	--	--	--
1988	306,500	30,600*	337,100	--
1989	410,700	--	--	--
1990	459,200	--	--	--
1991	329,200	28,000*	357,200	37,294
1992	414,000	--	--	--
1993	543,600	--	--	--
1994	570,600	--	--	107,019
1995	480,800	--	--	--
1996	556,400	--	--	--
1997	478,600	--	--	111,557
1998	344,900	--	--	--
1999	243,800			--
2000	340,400	--	--	93,515
2001	408,800	--	–	–
2002	355,100	61,200	416,300	88,700

*The 1988 and 1991 slope estimates were from the depth ranges of 200-800 m while earlier slope estimates were from 200-1,000 m. The 2002 slope estimate was from sampling conducted from 200-1,200 m.

Although the standard sampling trawl changed in 1982 to a more efficient trawl which may have caused an overestimate of the biomass increase in the pre-1982 part of the time-series, biomass estimates from AFSC surveys on the continental shelf have shown a consistent increasing trend since 1975. Since 1982, biomass point -estimates indicate that arrowtooth abundance has increased eight-fold to a high of 570,600 t in 1994. The population biomass remained at a high level from 1992-97. Results from the 1997-2000 bottom trawl surveys indicate the Bering Sea shelf population biomass had declined to 340,000 t, 60% of the peak 1994 biomass point estimate. The 2002 shelf survey estimate is higher at 355,100 t.

Arrowtooth flounder absolute abundance estimates are based on "area-swept" bottom trawl survey methods. These methods require several assumptions which can add to the uncertainty of the estimates. For example, it is assumed that the sampling plan covers the distribution of the species and that all fish in the path of the trawl are captured (no losses due to escape or gains due to herding). Due to sampling variability alone, the 95% confidence intervals for the 2002 point estimate are 292,100 - 418,100 t.

Trawl surveys on the continental slope estimate that arrowtooth flounder biomass increased significantly from 1982 to 1985. The biomass estimate in 1988 and 1991 were lower. However, sampling in 1988 and 1991 (200-800 m) was not as deep as in 1985 and earlier years (200-1,000 m). Based on slope surveys conducted between 1979 and 1985, 67 to 100% of the arrowtooth flounder biomass on the slope were found at depths less than 800 m. These data suggest that less than 20% of the total EBS population occupied slope waters in 1988 and 1991, a period of high arrowtooth flounder abundance. Surveys conducted during periods of low and increasing arrowtooth abundance (1979-85) indicate that 27% to 51% of the population weight occupied slope waters.

The eastern Bering Sea continental slope was surveyed in 2002 at depths ranging from 200 - 1,200 meters. The Poly Nor' Eastern bottom trawl net with mud sweep ground gear was the standard sampling net. Surveys conducted in 1988 and 1991 used a Nor' Eastern trawl with bobbin roller gear. Although this survey was deeper than earlier slope surveys, over 90% of the estimated arrowtooth biomasss was located in waters less than 800 meters. The 2002 slope estimate was 61,200 t.

Approximately 751.4 million fish were estimated for the eastern Bering Sea with most of the fish (704.9 million) occupying shelf waters and 46.5 million located on the continental slope. The Aleutian Islands region accounted for an additional 119 million arrowtooth flounder.

The combined arrowtooth/Kamchatka flounder abundance estimated from the 2002 Aleutian Islands trawl survey is 88,700 t, a continuation of the stable trend observed in the Aleutian Islands since 1994.

Weight-at-age, Length-at-age and Maturity-at-age

Parameters of the von Bertalanffy growth curve for arrowtooth flounder from age data collected during the 1982 U.S.-Japan cooperative survey and the 1991 slope survey (Zimmermann and Goddard 1995) are as follows:

Sex	Sample size	Age range	L_{inf}	k	t_o
1982 age sample					
Male	528	2-14	45.9	0.23	-0.70
Female	706	2-14	73.8	0.14	-0.20
Sexes Combined	1,234	2-14	59.0	0.17	-0.50
1991 age sample					
Male	53	3-9	57.9	0.17	-2.17
Female	134	4-12	85.0	0.16	-0.81

Based on 282 observations during a AFSC survey in 1976, the length (mm)-weight (gm) relationship for arrowtooth flounder (sexes combined) is described by the equation:

$$W = 5.682 \times 10^{-6} * L ** 3.1028.$$

Maturity information from a histological examination of arrowtooth flounder in the Gulf of Alaska (Zimmerman 1997) indicate that male and female fish become 50% mature at 46.9 and 42.2 cm, respectively.

ANALYTIC APPROACH

Model Structure

The arrowtooth flounder stock assessment for the year 2003 fishing season will be conducted with a change of implementation software. The AD Model Builder language is used to re-write the established population dynamics model (stock synthesis model was used from 1995 - 2001). The model is a length-based approach where survey and fishery length composition observations are used to calculate estimates of population numbers-at-age by the use of a length-age (growth) matrix. The model simulates the dynamics of the population and compares the expected values of the population characteristics to the those observed from surveys and fishery sampling programs. This is accomplished by the simultaneous estimation of the parameters in the model using the maximum likelihood estimation procedure. The fit of the simulation values to the observed characteristics is optimized by maximizing the log(likelihood) function.

The suite of parameters estimated by the model are classified by three likelihood components:

Data Component	Distribution assumption
Trawl fishery size composition	Multinomial
Shelf survey population size composition	Multinomial
Slope survey population size composition	Multinomial
Trawl survey biomass estimates and S.E.	Log normal

The total log likelihood is the sum of the likelihoods for each data component (see Table 6-6). The model allows for the individual likelihood components to be weighted by an emphasis factor. The parameters estimated by the model are presented below:

Fishing mortality	Selectivity	Year class strength	Total
27	16	45	88

The recruitment parameters are comprised of 21 initial age in 1976 and 24 age 1 recruitment estimates from 1976-2000. Recruitment is 2001 and 2002 was set at the average from 1976-2000. The difference in the number of parameters estimated in this assessment compared to last year can be accounted for by starting the model in 1976 instead of 1970 (when only catch data was available) and the addition of the 2002 shelf and slope survey data.

We assume that the shelf and slope surveys measure non-overlapping segments of the arrowtooth flounder stock. The model was configured with the Bering Sea shelf comprising 87% of the population, calculated from the average proportion of shelf/shelf+slope biomass from the trawl survey time-series. In this assessment we did not attempt to incorporate the Aleutian Islands biomass estimate. For Bering Sea shelf flatfish, the accepted belief is that the trawl survey is a good indicator of the flatfish abundance level. Thus, it is desirable to obtain a reasonable fit to this data component and the model was configured with an emphasis of 5.0 was placed on fitting the shelf survey biomass trend. This resulted in a better fit to the abundance trend and only minimally affected the fit to the other primary data components.

The most reliable and consistent data for modeling the arrowtooth flounder population are the shelf survey biomass and size composition time-series. Consequently, results are most closely linked to fitting the general trend of increasing shelf survey biomass estimates during the 1980s to its peak level in the mid-1990s, and to fitting the male and female size compositions from the shelf survey (Fig. 5.2).

Parameters Estimated Independently

Catchability

A past assessment (Wilderbuer and Sample 1995) also analyzed the value of Q or catchability of the research trawl by examining fits of the models' various likelihood components over a range of fixed Q values. The results indicated that Q = 2.0 which suggests that more fish are caught in the survey trawl than are present in the "effective" fishing width of the trawl (ie. some herding may occur or the "effective" fishing width of the trawl may be the distance between the doors instead of between the wingtips of the survey trawl). However, since only one sample of age structures has been read for Bering Sea arrowtooth flounder, it may not be possible to obtain reliable estimates of q for this stock. Therefore a value of q = 0.87 is used to fit the shelf survey biomass estimates and a value of q = 0.13 used to fit the slope survey biomass

Parameters Estimated Conditionally

Year class strengths

The population simulation specifies the number-at-age in the beginning year of the simulation, the number of recruits in subsequent years, and the survival rate for each cohort as it moves through the population calculated from the population dynamics equations (see Table 6-6).

Fishing Mortality

The fishing mortality rates (F) for each age and year are calculated to approximate the catch weight by solving for F while still allowing for observation error in catch measurement. A large emphasis was placed on the catch likelihood component.

Selectivity and sex ratio

Survey results indicate that fish less than about 4 years old (< 30 cm) are found only on the Bering Sea shelf. Males from 30-50 cm and females 30-70 cm are found in shelf and slope waters, and males > 50 cm and females > 70 cm are found exclusively on the slope. Sex specific "domed-shaped" selectivity was freely estimated for the shelf survey; for the slope survey we assumed an asymptotic selectivity pattern.

At the present time there is no directed fishery for arrowtooth flounder in the eastern Bering Sea. Length measurements collected from the fishery represent opportunistic samples of arrowtooth flounder taken as bycatch. This results in sample size problems which make estimates of fishery selectivity unreliable. Also, we felt that a directed fishery would likely target a different segment of the stock. Accordingly, the shape of the selectivity curve was fixed asymptotic for older fish in the fishery since a directed fishery would presumably target on larger fish. This also allowed for a realistic calculation of exploitable biomass from the model estimate of total biomass.

The natural mortality of arrowtooth flounder is assumed to be 0.20. This estimate was used because it is similar to that of other species of flatfish with approximately the same age range as arrowtooth flounder and is the same estimate used by Okada et al. (1980). However, examination of the shelf and slope survey population estimates indicate that females are consistently estimated to be in higher abundance than males (Fig. 5.3). This difference was also evident in the Gulf of Alaska from triennial surveys conducted from 1984-96 (Turnock et al. 1998). This information was incorporated into a past assessment by adjusting the size composition data input into the model by the sex ratio proportion observed in shelf and slope trawl surveys and fishery data. This resulted in unsatisfactory results as the model gave low estimates of male selectivity which has the undesirable result of artificially increasing population estimates. Changing to the AD Model software allows alternative modeling of the population which does not require an assumption of equal sex ratio as in past assessments.

Possible reasons for the higher estimates of females in the survey observations may be: 1) there is a spatial separation of males and females where males are less available to the survey trawl, 2) there is a higher natural mortality for males than females, 3) there are some sampling problems, or 4) there is a genetic predisposition to produce more females than males.

Since we do not believe that male arrowtooth flounder are less available to the Bering Sea shelf survey sampling trawl than females, differential sex-specific natural mortality was investigated in an alternative model as an explanation of the observed differences in catch sex ratio.

Alternative Modeling

Model runs were made with female natural mortality fixed at 0.2 for a range of values for males. Model runs were evaluated with respect to the estimate of male selectivity for the shelf survey. When natural mortality is set at 0.2 for both sexes, the model estimates that maximum selectivity for males is 0.49 at age 7. When additional model runs are made with increasing natural mortality values for males it is evident that natural mortality and selectivity estimates in the model are confounded and male selectivity increases with increasing natural mortality. Model results shown below indicate that increased male selectivity at increased natural mortality rate results in lower population and biomass estimates up to M=0.28. The selectivities for females (not shown) were always maximum at age 5 but the proportion selected decreased slightly when male natural mortality was set at 0.281 or greater.

Male natural mortality rate	**maximum male selectivity**	**age at maximum male selectivity**	**2002 biomass estimate (t)**
0.2	0.49	7	803,000
0.25	0.63	10	669,400
0.28	0.87	14	622,600
0.281	1.0	15	638,000
0.29	1.0	15	661,400
0.3	1.0	15	688,200

The model run with natural mortality for males fixed at 0.281 and females at 0.2 is the preferred run because there is only a slight decline to the estimate of maximum female selectivity at age 5 (0.91) and is the lowest value of male natural mortality which estimates a maximum selectivity for males of 1.0 at age 15. This is consistent with our hypothesis that the differences in sex ratios observed in catches of arrowtooth flounder throughout the Bering Sea, Aleutian Islands and the Gulf of Alaska result from differential sex-specific survival rates and are not due to distributional or behavior differences. Differences in estimated length-based selectivities by sex, are due to slower growth in males.

MODEL RESULTS

Fishing mortality and selectivity

The stock assessment model estimates of the annual fishing mortality on fully selected ages and the estimated annual exploitation rates (catch/total biomass) are given in Table 5.2. The average exploitation rate has been at a low level, 4%, from 1977-1999 due to the relative undesirability of arrowtooth flounder as a commercial product. Age-specific selectivity estimated by the model (Table 5.3, Fig. 5.4) indicate that arrowtooth flounder are 50% selected by the fishery at about 9 and 8 years of age and are fully selected by ages 18 and 16, for males and females, respectively.

Abundance Trend

Model estimates indicate that arrowtooth flounder total biomass increased nearly 5 fold from 1980 to its' most abundant level in 1996 at 817,700 t (Fig. 5.5, Table 5.4). The biomass has declined 22% since then to the 2002 estimate of 638,000 t. Female spawning biomass is also estimated to be at high level, 479,700 t in 2002 (Table 5.4). Model estimates of population numbers by age, year, and sex are given in Table 5.5.

The model fit to the shelf survey (emphasis 5.0) tracks the abundance trend well through the time-series. The model estimate of survey biomass is less than the highest observed values in 1993, 1994 and 1996 and does not provide a good fit to the recent low estimates observed in 1998-2000, although it provides a good fit to the 2002 estimate. The model indicates an increasing biomass trend on the slope and provides a reasonable fit to the 2002 slope survey estimate (Fig. 5.5). The slope biomass represents a smaller fraction of the total stock and was considered to be poorly estimated by the 1991 survey which is considered an underestmate due to the reduction in sampling depth relative to earlier surveys.

The model provided a good fit to the survey shelf size composition time-series since 1981 for males and females (1989-99), which are shown in the Appendix. Reasonable fits also resulted for slope survey size composition observations.

Recruitment Trends

Increases in abundance from 1983-95 were the result of 5 strong year-classes spawned in 1981, 1984, 1986, 1987 and 1988 (Fig. 5.6, Table 5.6). Since 1990, recruitment is estimated to be near average in 1989-91 and below average thereafter.

Otoliths for aging arrowtooth flounder have been routinely collected during AFSC surveys in the EBS, but they have been infrequently aged because of higher priority for aging other species. However, an examination of length-frequency data shows that modes formed by age groups 1 to 3 are reasonably well separated so that fish less than 25 cm can be used as a measure of recruitment for age 2 fish; some age 1 fish are also included, but they are poorly recruited to the survey trawls. Population estimates (in millions) for fish less than 25 cm are as follows:

Year	1982	1983	1984	1985	1986	1987	1988	1989	1990
Population estimates	86.1	290.2	57.9	62.4	150.3	94.3	200.6	273.8	105.2

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Population estimates	71.7	79.4	96.8	126.6	75.1	55.6	108.8	93.6	92.1	126.3

Year	2001	2002
Population estimates	164.3	108.8

Over this period, population estimates for this size group have averaged 115 million. Above average recruitment has occurred in 1983, 1986, 1988, 1989, 1994 and 2000. Since the estimates primarily represent age 2 fish, the year-classes producing the strong recruitment are 1981, 1984, 1986, 1987, 1992 and 1998. Estimates of age 2 recruitment from the stock assessment model fits this information in the population simulation and indicates average to above average recruitment for the four years following the large 1986 and 1987 year-classes (fig. 5.6). Age 2 recruitment since 1992 is estimated to be well below the levels observed during the 1980s.

ACCEPTABLE BIOLOGICAL CATCH

Arrowtooth flounder have a wide-spread bathymetric distribution in the Bering Sea/Aleutian Islands region and are believed to be at a high level, primarily as a result of five strong year-classes spawned during the 1980s and minimal commercial harvest. They are estimated to have declined more than 20% since a peak population biomass in 1995. **The estimate of 2003 total biomass from the stock assessment model is 596,600 t and the female spawning biomass is estimated at 436,400 t (not including the Aleutian Islands)**.

The reference fishing mortality rate for arrowtooth flounder is determined by the amount of reliable population information available (Amendment 56 of the Fishery Management Plan for the groundfish fishery of the Bering Sea/Aleutian Islands). Equilibrium female spawning biomass is calculated by applying the female spawning biomass per recruit resulting from a constant $F_{0.40}$ harvest to an estimate of average equilibrium recruitment. Year classes spawned in 1977-2001 are used to calculate the average equilibrium recruitment. Using the time-series of age 1 recruitment from 1978-2002 from the stock assessment model results in an estimate of $B_{0.40}$ = 206,300 t. The stock assessment model estimates the 2003 level of female spawning biomass at 436,400 t (B). Since reliable estimates of B, $B_{0.40}$, $F_{0.40}$, and $F_{0.30}$ exist and B>$B_{0.40}$ (436,400 > 206,300), arrowtooth flounder reference fishing mortality is defined in tier 3a. For the 2003 harvest: $F_{ABC} \leq F_{0.40} = 0.30$ and $F_{overfishing} = F_{0.35} = 0.38$ (full selection F values).

Acceptable biological catch is estimated for 2003 by applying the $F_{0.40}$ fishing mortality rate and age-specific fishery selectivities to the projected 2003 estimate of age-specific total biomass as follows:

$$ABC = \sum_{a=a_r}^{a_{nages}} \overline{w}_a n_a \left(1 - e^{-M - Fs_a}\right) \frac{Fs_a}{M + Fs_a}$$

where S_a is the selectivity at age, M is natural mortality, W_a is the mean weight at age, and n_a is the beginning of the year numbers at age. **This results in a 2003 ABC of 112,300 t.**

The potential yield of arrowtooth flounder for 2003 at various levels of fishing mortality (full selection) are as follows:

F level	Exploitation rate	Potential yield
$F_{overfishing}$	0.38	139,000 t
$F_{0.40}$	**0.30**	**112,300 t**

PROJECTED BIOMASS

A standard set of projections is required for each stock managed under Tiers 1, 2, or 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Protection Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2002 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2003 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2002 (9,131 t). In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2003, are as follow ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2003 recommended in the assessment to the *max* F_{ABC} for 2003. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, F is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 1998-2002 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follow (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above ½ of its MSY level in 2003 and above its MSY level in 2013 under this scenario, then the stock is not overfished.)

Scenario 7: In 2003 and 2004, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2015 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results (Table 5.7) indicate that arrowtooth flounder are not currently overfished and the stock is not considered to be approaching an overfished condition.

OTHER CONSIDERATIONS

Arrowtooth flounder are currently of limited economic importance as a fisheries product, however, trophic studies (Lang et al. 1991, Livingston et al. 1993) indicate they are an important predator and may be an important component in understanding the dynamics of the Bering Sea benthic ecosystem. This is particularly relevant as the Council considers shifting emphasis from single species to multi-species fisheries management of the Bering Sea and Aleutian Islands (Ecosystem Considerations, 1994 SAFE). Trophic studies indicate that the main food item in the diet of arrowtooth flounder is fish, particularly for arrowtooth larger than 30 cm. Pollock are a major component of the diet as well as other fish such as zoarcids. Invertebrates are also important and include cephalopods, euphausiids and pandalid and crangonid shrimp. Preadators of arrowtooth flounder include Pacific cod and large pollock, mostly on juvenile fish.

5.9 REFERENCES

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Table 5.1.--All nation total catch (t) of arrowtooth flounder in the eastern Bering Sea and Aleutian Islands region[a], 1970-2002. Catches since 1990 are not reported by area.

	Eastern Bering Sea				Aleutian Island Region				
Year	Non-U.S. fisheries[b]	U.S. J.V.[c]	U.S. DAH	Total	Non-U.S. fisheries	U.S. J.V.	U.S. DAH	Total	Total
1970	12,598			12,598	274			274	12,872
1971	18,792			18,792	581			581	19,373
1972	13,123			13,123	1,323			1,323	14,446
1973	9,217			9,217	3,705			3,705	12,922
1974	21,473			21,473	3,195			3,195	24,668
1975	20,832			20,832	784			784	21,616
1976	17,806			17,806	1,370			1,370	19,176
1977	9,454			9,454	2,035			2,035	11,489
1978	8,358			8,358	1,782			1,782	10,140
1979	7,921			7,921	6,436			6,436	14,357
1980	13,674	87		13,761	4,603			4,603	18,364
1981	13,468	5		13,473	3,624	16		3,640	17,113
1982	9,065	38		9,103	2,356	59		2,415	11,518
1983	10,180	36		10,216	3,700	53		3,753	13,969
1984	7,780	200		7,980	1,404	68		1,472	9,452
1985	6,840	448		7,288	11	59	89	159	7,447
1986	3,462	3,298	5	6,766		78	337	415	7,181
1987	2,789	1,561	158	4,508		114	237	351	4,859
1988		2,552	15,395	17,947		22	2,021	2,043	19,990
1989		2,264	4,000	6,264			1,042	1,042	7,306
1990		660	7,315	7,975			5,083	5,083	13,058
1991									22,052
1992									10,382
1993									9,338
1994									14,366
1995									9,280
1996									14,652
1997									10,054
1998									15,241
1999									10,573
2000									12,929
2001									13,908
2002*									9,131

[a]Catches from data on file Alaska Fisheries Science Center, 7600 Sand Point Way N.E., Seattle, WA 98115.
[b]Japan, U.S.S.R., Republic of Korea, Taiwan, Poland, and Federal Republic of Germany.
[c]Joint ventures between U.S. fishing vessels and foreign processing vessels.
*Catch information through 14 September, 2002 (NMFS regional office).

Table 5.2 --Model estimates of arrowtooth flounder fishing mortality and exploitation rate (catch/total biomass).

year	Full selection F	Exploitation rate
1976	0.247	0.115
1977	0.167	0.073
1978	0.150	0.062
1979	0.215	0.085
1980	0.288	0.104
1981	0.291	0.093
1982	0.187	0.055
1983	0.200	0.058
1984	0.115	0.034
1985	0.074	0.023
1986	0.058	0.019
1987	0.032	0.011
1988	0.108	0.039
1989	0.034	0.013
1990	0.052	0.020
1991	0.077	0.031
1992	0.032	0.014
1993	0.025	0.012
1994	0.034	0.018
1995	0.020	0.011
1996	0.029	0.018
1997	0.020	0.013
1998	0.029	0.019
1999	0.021	0.014
2000	0.026	0.018
2001	0.029	0.020
2002	0.020	0.014

Table 5.3--Model estimates of arrowtooth flounder age-specific fishery and survey selectivities, by sex.

Age	females	males	females	males	females	males
1	0.001	0.003	0.034	0.106	0.000	0.019
2	0.003	0.006	0.144	0.163	0.000	0.030
3	0.008	0.014	0.448	0.244	0.000	0.049
4	0.023	0.031	0.792	0.349	0.003	0.079
5	0.061	0.067	0.906	0.472	0.055	0.123
6	0.152	0.138	0.890	0.601	0.555	0.188
7	0.331	0.262	0.841	0.720	0.964	0.277
8	0.578	0.442	0.786	0.817	0.998	0.387
9	0.792	0.638	0.731	0.889	1.000	0.510
10	0.913	0.797	0.678	0.938	1.000	0.632
11	0.967	0.897	0.627	0.969	1.000	0.739
12	0.988	0.951	0.578	0.987	1.000	0.823
13	0.996	0.977	0.531	0.996	1.000	0.885
14	0.998	0.990	0.487	1.000	1.000	0.927
15	0.999	0.995	0.446	1.000	1.000	0.954
16	1.000	0.998	0.407	0.998	1.000	0.972
17	1.000	0.999	0.371	0.995	1.000	0.983
18	1.000	1.000	0.337	0.991	1.000	0.989
19	1.000	1.000	0.306	0.987	1.000	0.994
20	1.000	1.000	0.277	0.982	1.000	0.996
21	1.000	1.000	0.251	0.977	1.000	0.998

Table 5.4--Model estimates of arrowtooth flounder 2+ total biomass and female spawning biomass from the 2001 and 2002 assessments.

	2001 Assessment		2002 Assessment	
	age 1+ Total biomass	Female Spawning biomass	age 1+ Total biomass	Female Spawning biomass
1976	123,448	54,127	167,756	102,751
1977	119,652	52,505	159,384	96,302
1978	128,336	53,718	162,749	94,366
1979	142,723	54,614	172,207	92,966
1980	156,296	54,622	180,536	90,394
1981	172,201	55,190	192,481	91,497
1982	200,164	64,297	210,174	98,576
1983	239,908	78,938	242,341	110,170
1984	279,951	88,926	279,260	121,895
1985	333,046	109,249	323,816	150,710
1986	393,955	145,379	377,002	190,017
1987	464,410	179,579	440,148	219,913
1988	549,482	206,601	508,824	256,853
1989	626,801	238,940	569,152	292,906
1990	715,566	285,960	641,304	336,917
1991	788,043	332,417	701,399	387,350
1992	837,320	387,937	740,905	441,685
1993	881,268	444,838	780,969	492,118
1994	907,202	483,870	807,618	528,082
1995	909,050	504,089	816,157	547,116
1996	900,273	518,070	817,749	562,438
1997	874,358	520,490	803,520	564,034
1998	844,271	515,001	786,500	558,777
1999	803,872	496,004	756,434	540,877
2000	764,041	480,966	724,719	525,870
2001	718,572	447,525	684,381	505,741
2002	671,188	423,378	637,958	479,703

Table 5.5--Model estimates of arrowtooth flounder population number-at-age, by sex, 1976-2002.

females — numbers at age (1,000s)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1976	79,994	40,847	27,024	22,312	46,956	20,522	9,529	6,662	5,234	4,251	3,528	2,984	2,563	2,229	1,952	1,719	1,515	1,342	1,175	1,028	2,344
1977	136,880	65,476	33,417	22,079	18,165	37,872	16,183	7,188	4,728	3,524	2,777	2,275	1,914	1,641	1,425	1,248	1,099	969	858	751	2,156
1978	87,256	112,048	53,580	27,322	18,008	14,722	30,229	12,535	5,342	3,390	2,476	1,934	1,578	1,326	1,136	987	864	761	671	594	2,014
1979	94,595	71,427	91,695	43,813	22,293	14,611	11,783	23,553	9,412	3,885	2,421	1,754	1,366	1,114	935	801	696	609	537	473	1,838
1980	125,495	77,430	58,442	74,939	35,695	18,015	11,578	8,983	17,025	6,498	2,613	1,610	1,161	902	735	617	529	459	402	354	1,526
1981	303,717	102,714	63,339	47,733	60,953	28,718	14,118	8,616	6,225	11,095	4,089	1,619	991	713	554	451	379	325	282	247	1,154
1982	124,556	248,583	84,021	51,731	38,822	49,029	22,495	10,495	5,960	4,046	6,961	2,526	994	607	437	339	276	232	199	172	857
1983	110,014	101,957	203,407	68,684	42,174	31,427	39,021	17,313	7,714	4,209	2,794	4,758	1,720	676	413	297	230	188	157	135	699
1984	330,886	90,052	83,425	166,258	55,978	34,113	24,962	29,902	12,628	5,392	2,872	1,886	3,198	1,154	453	277	199	154	126	106	559
1985	220,136	270,873	73,703	68,237	135,765	45,513	27,448	19,675	22,911	9,442	3,975	2,104	1,379	2,336	843	331	202	145	113	92	485
1986	208,528	180,218	221,722	60,306	55,773	110,656	36,846	21,927	15,432	17,688	7,224	3,029	1,601	1,048	1,776	641	252	154	110	86	439
1987	489,105	170,717	147,524	181,442	49,309	45,502	89,800	29,590	17,357	12,065	13,731	5,591	2,342	1,237	810	1,372	495	194	119	85	405
1988	251,116	400,432	139,758	120,750	148,445	40,293	37,075	72,751	23,785	13,858	9,595	10,902	4,436	1,857	981	642	1,088	392	154	94	389
1989	238,424	205,572	327,738	114,321	98,618	120,740	32,451	29,285	55,948	17,874	10,278	7,075	8,020	3,260	1,365	721	472	799	288	113	355
1990	167,323	195,198	168,291	268,253	93,526	80,576	98,346	26,272	23,511	44,593	14,187	8,143	5,602	6,348	2,581	1,080	571	373	633	228	370
1991	195,287	136,984	159,789	137,725	219,365	76,329	65,448	79,135	20,868	18,468	34,806	11,043	6,331	4,354	4,933	2,005	839	443	290	492	465
1992	164,029	159,873	112,127	130,740	112,561	178,760	61,764	52,228	61,955	16,071	14,089	26,443	8,376	4,799	3,299	3,738	1,519	636	336	220	725
1993	151,358	134,291	130,881	91,777	106,963	91,979	145,650	50,037	41,980	49,461	12,780	11,185	20,979	6,643	3,806	2,617	2,965	1,205	504	266	749
1994	87,898	123,918	109,940	107,134	75,098	87,442	75,022	118,270	40,382	33,700	39,586	10,215	8,935	16,756	5,306	3,040	2,090	2,368	962	403	811
1995	140,132	71,962	101,445	89,986	87,646	61,359	71,225	60,739	94,957	32,189	26,753	31,368	8,089	7,073	13,263	4,200	2,406	1,654	1,874	762	961
1996	139,247	114,728	58,914	83,043	73,641	71,673	50,086	57,934	49,164	76,538	25,883	21,489	25,186	6,493	5,678	10,647	3,371	1,931	1,328	1,504	1,383
1997	97,797	114,002	93,923	48,223	67,944	60,185	58,420	40,610	46,633	39,327	61,005	20,598	17,091	20,026	5,163	4,514	8,464	2,680	1,535	1,056	2,295
1998	93,174	80,068	93,331	76,885	39,464	55,562	49,129	47,521	32,874	37,592	31,627	49,009	16,541	13,722	16,078	4,145	3,624	6,796	2,152	1,233	2,690
1999	57,744	76,282	65,548	76,394	62,906	32,252	45,287	39,832	38,249	26,294	29,960	25,166	38,974	13,151	10,909	12,782	3,295	2,881	5,402	1,711	3,119
2000	41,045	47,276	62,450	53,657	62,517	51,438	26,323	36,824	32,223	30,805	21,123	24,042	20,186	31,256	10,546	8,748	10,250	2,642	2,310	4,332	3,872
2001	42,900	33,604	38,703	51,119	43,905	51,103	41,947	21,366	29,697	25,842	24,626	16,863	19,182	16,103	24,931	8,412	6,978	8,175	2,107	1,843	6,544
2002	42,900	35,122	27,510	31,680	41,824	35,882	41,653	34,010	17,197	23,753	20,595	19,596	13,410	15,251	12,801	19,819	6,687	5,547	6,499	1,675	6,667

Table 5.5--Continued.

males numbers at age (1,000s)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1976	79,994	37,669	22,982	17,499	33,961	13,688	5,861	3,779	2,738	2,051	1,570	1,224	970	778	628	510	415	339	273	221	343
1977	136,880	60,354	28,395	17,291	13,110	25,220	9,988	4,147	2,558	1,766	1,271	949	731	575	460	371	301	244	200	161	332
1978	87,256	103,298	45,520	21,388	12,987	9,788	18,608	7,218	2,908	1,736	1,167	826	611	468	368	294	237	192	156	127	315
1979	94,595	65,852	77,918	34,295	16,073	9,708	7,240	13,509	5,101	1,996	1,163	770	541	399	305	239	191	154	125	102	288
1980	125,495	71,377	49,651	58,649	25,720	11,962	7,115	5,166	9,274	3,357	1,269	724	474	331	243	186	146	116	94	76	237
1981	303,717	94,673	53,791	37,334	43,885	19,048	8,680	4,981	3,434	5,826	2,014	740	416	270	188	138	105	82	66	53	177
1982	124,556	229,120	71,346	40,445	27,932	32,493	13,816	6,071	3,306	2,153	3,487	1,171	423	236	153	106	78	59	47	37	130
1983	110,014	93,992	172,783	53,725	30,360	20,828	23,911	9,933	4,221	2,216	1,401	2,227	740	266	148	96	67	49	37	29	105
1984	330,886	83,016	70,875	130,084	40,311	22,618	15,299	17,131	6,866	2,806	1,427	884	1,391	460	165	92	59	41	30	23	83
1985	220,136	249,745	62,633	53,425	97,866	30,203	16,809	11,209	12,296	4,818	1,933	972	599	939	310	111	62	40	28	20	71
1986	208,528	166,173	188,474	47,239	40,244	73,525	22,572	12,447	8,190	8,855	3,429	1,366	684	420	658	217	78	43	28	19	64
1987	489,105	157,418	125,418	142,185	35,602	30,267	55,070	16,784	9,159	5,958	6,382	2,457	976	488	300	469	155	56	31	20	60
1988	251,116	369,254	118,830	94,651	107,247	26,823	22,753	41,234	12,496	6,776	4,386	4,683	1,800	714	357	219	343	113	41	23	58
1989	238,424	189,540	278,602	89,582	71,223	80,389	19,953	16,698	29,678	8,805	4,693	3,005	3,190	1,223	484	242	149	233	77	28	55
1990	167,323	179,999	143,077	210,251	67,565	53,653	60,413	14,931	12,420	21,928	6,471	3,437	2,197	2,330	893	354	177	108	170	56	60
1991	195,287	126,314	135,858	107,946	158,486	50,835	40,219	44,992	11,016	9,069	15,880	4,662	2,469	1,576	1,670	640	253	127	78	122	83
1992	164,029	147,414	95,323	102,464	81,306	119,043	37,975	29,756	32,828	7,917	6,438	11,186	3,270	1,729	1,102	1,168	447	177	88	54	143
1993	151,358	123,835	111,278	71,939	77,286	61,257	89,487	28,433	22,153	24,288	5,828	4,724	8,194	2,393	1,265	806	854	327	130	65	144
1994	87,898	114,271	93,484	83,989	54,274	58,256	46,093	67,126	21,233	16,463	17,978	4,303	3,483	6,038	1,763	932	594	629	241	95	154
1995	140,132	66,359	86,259	70,549	63,347	40,885	43,781	34,494	49,931	15,690	12,100	13,169	3,146	2,545	4,409	1,287	680	433	459	176	182
1996	139,247	105,798	50,096	65,110	53,234	47,765	30,786	32,885	25,818	37,227	11,661	8,975	9,758	2,330	1,884	3,264	953	503	321	340	265
1997	97,797	105,126	79,865	37,808	49,115	40,114	35,919	23,066	24,509	19,131	27,457	8,576	6,590	7,159	1,709	1,382	2,393	699	369	235	443
1998	93,174	73,836	79,363	60,284	28,529	37,034	30,206	26,981	17,265	18,275	14,221	20,370	6,355	4,881	5,301	1,265	1,023	1,772	517	273	502
1999	57,744	70,343	55,737	59,896	45,474	21,498	27,849	22,630	20,107	12,793	13,478	10,457	14,954	4,662	3,579	3,887	928	750	1,299	379	569
2000	41,045	43,596	53,104	42,071	45,194	34,286	16,185	20,912	16,930	14,982	9,500	9,988	7,741	11,064	3,448	2,647	2,874	686	555	961	701
2001	42,900	30,988	32,910	40,080	31,739	34,063	25,794	12,137	15,608	12,572	11,079	7,007	7,356	5,697	8,140	2,537	1,947	2,114	505	408	1,222
2002	42,900	32,388	23,392	24,838	30,233	23,916	25,614	19,325	9,045	11,565	9,272	8,146	5,144	5,396	4,178	5,969	1,860	1,428	1,550	370	1,195

Table 5.6--Estimated age 2 recruitment of arrowtooth flounder (thousands of fish) from the 2001 and 2002 assessments.

Year class	2001 Assessment	2002 Assessment
1974	77,758	78,515
1975	69,268	125,830
1976	115,406	215,346
1977	230,948	137,279
1978	81,544	148,807
1979	122,508	197,387
1980	296,342	477,703
1981	395,687	195,949
1982	88,234	173,068
1983	222,990	520,618
1984	566,824	346,391
1985	201,582	328,135
1986	601,336	769,686
1987	562,452	395,112
1988	353,342	375,197
1989	253,492	263,298
1990	218,834	307,287
1991	286,408	258,126
1992	186,802	238,189
1993	131,616	138,320
1994	100,422	220,526
1995	183,420	219,128
1996	128,330	153,903
1997	128,658	146,624
1998	140,014	90,871
1999		64,592

Table 5.7--Projections of arrowtooth flounder female spawning biomass (t), future catch (t) and full selection fishing mortality rates for seven future harvest scenarios.

Scenarios 1 and 2
Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2002	471,081	9,131	0.02
2003	436,386	112,316	0.30
2004	324,063	83,430	0.30
2005	240,904	62,270	0.30
2006	181,671	41,521	0.26
2007	151,216	27,441	0.21
2008	147,169	22,918	0.21
2009	155,150	22,719	0.22
2010	167,417	25,305	0.23
2011	179,809	29,295	0.25
2012	189,950	33,160	0.26
2013	197,141	36,154	0.27
2014	202,294	38,231	0.27
2015	205,836	39,588	0.28

Scenario 3
1/2 Maximum ABC harvest permissible

Year	Female spawning biomass	catch	F
2002	471,081	9,131	0.02
2003	441,126	59,831	0.15
2004	369,758	50,531	0.15
2005	307,537	42,464	0.15
2006	255,766	35,492	0.15
2007	220,848	29,700	0.15
2008	206,520	24,519	0.14
2009	205,896	21,872	0.14
2010	212,603	21,654	0.14
2011	222,685	22,911	0.14
2012	233,473	24,728	0.14
2013	243,441	26,542	0.15
2014	252,527	28,160	0.15
2015	260,374	29,481	0.15

Scenario 4
Harvest at average F over the past 5 years

Year	Female spawning biomass	catch	F
2002	471,081	9,131	0.02
2003	445,368	7,272	0.02
2004	416,268	6,892	0.02
2005	384,450	6,461	0.02
2006	353,081	5,988	0.02
2007	330,443	5,508	0.02
2008	321,906	5,079	0.02
2009	322,190	4,787	0.02
2010	327,648	4,690	0.02
2011	336,712	4,771	0.02
2012	347,948	4,962	0.02
2013	360,209	5,205	0.02
2014	373,232	5,460	0.02
2015	386,329	5,710	0.02

Scenario 5
No fishing

Year	Female spawning biomass	catch	F
2002	471,081	0	0
2003	445,921	0	0
2004	422,759	0	0
2005	395,912	0	0
2006	368,538	0	0
2007	348,954	0	0
2008	342,582	0	0
2009	344,313	0	0
2010	350,722	0	0
2011	360,513	0	0
2012	372,460	0	0
2013	385,554	0	0
2014	399,579	0	0
2015	413,867	0	0

Table 5.7—continued.

Scenario 6
Determination of whether arrowtooth flounder are currently overfished

B35=180,500 t

Year	Female spawning biomass	catch	F
2002	471,081	9,131	0.02
2003	433,735	139,052	0.38
2004	301,107	96,159	0.38
2005	210,762	67,300	0.38
2006	151,841	36,046	0.27
2007	129,016	24,561	0.23
2008	129,866	21,628	0.23
2009	140,970	22,710	0.25
2010	154,908	26,540	0.28
2011	167,607	31,583	0.30
2012	176,962	36,041	0.32
2013	182,770	39,152	0.33
2014	186,418	41,063	0.33
2015	188,617	42,137	0.33

Scenario 7
Determination of whether arrowtooth flounder are approaching an overfished condition

B35=180,500 t

Year	Female spawning biomass	catch	F
2002	471,081	9,131	0.02
2003	436,386	112,316	0.30
2004	324,063	83,430	0.30
2005	239,444	77,114	0.38
2006	169,373	45,095	0.31
2007	137,591	28,229	0.25
2008	134,425	23,451	0.24
2009	143,363	23,683	0.26
2010	156,064	27,037	0.28
2011	168,081	31,797	0.30
2012	177,100	36,100	0.32
2013	182,769	39,144	0.33
2014	186,375	41,036	0.33
2015	188,573	42,111	0.33

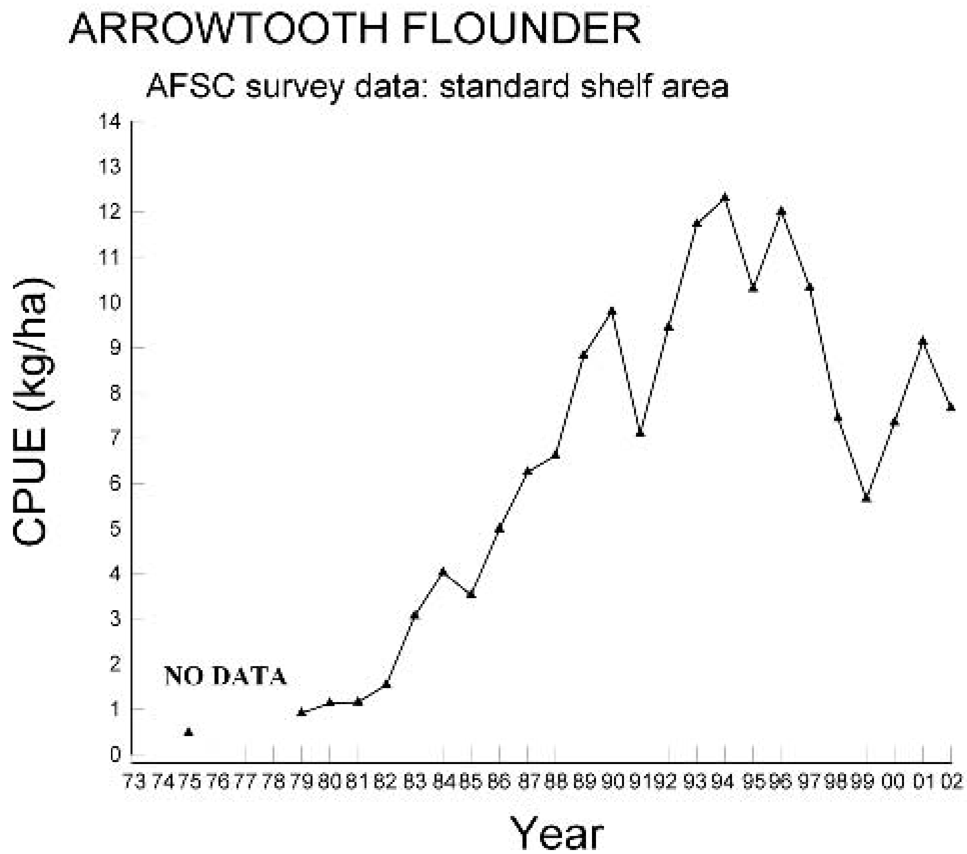


Figure 5.1--Catch per unit effort (CPUE) of arrowtooth flounder on the eastern Bering Sea continental shelf as shown by Alaska Fisheries Science Center (AFSC) survey data.

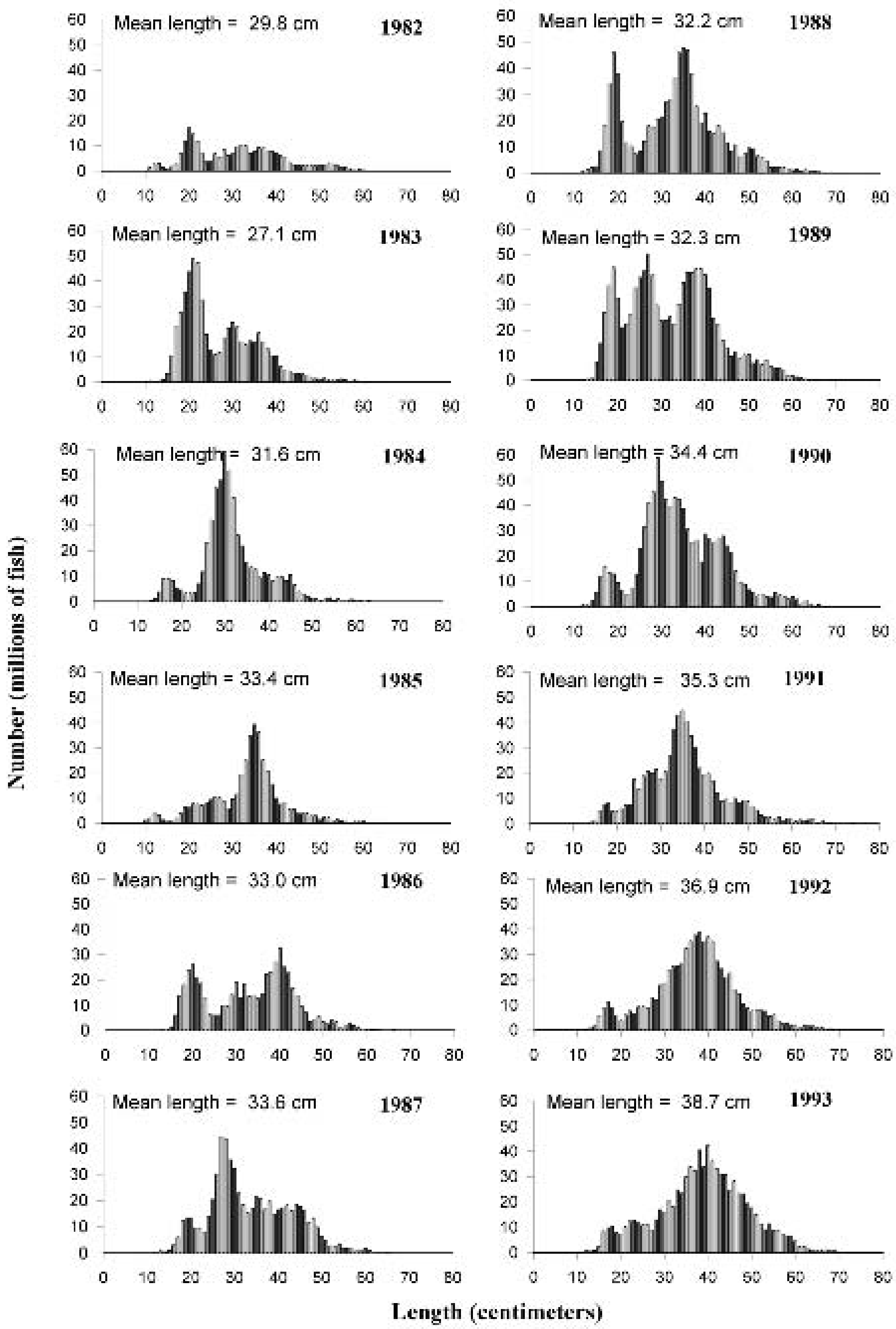


Figure 5.2-- Size composition (millions of fish) of arrowtooth flounder from the eastern Bering Sea bottom trawl surveys during 1982-2002.

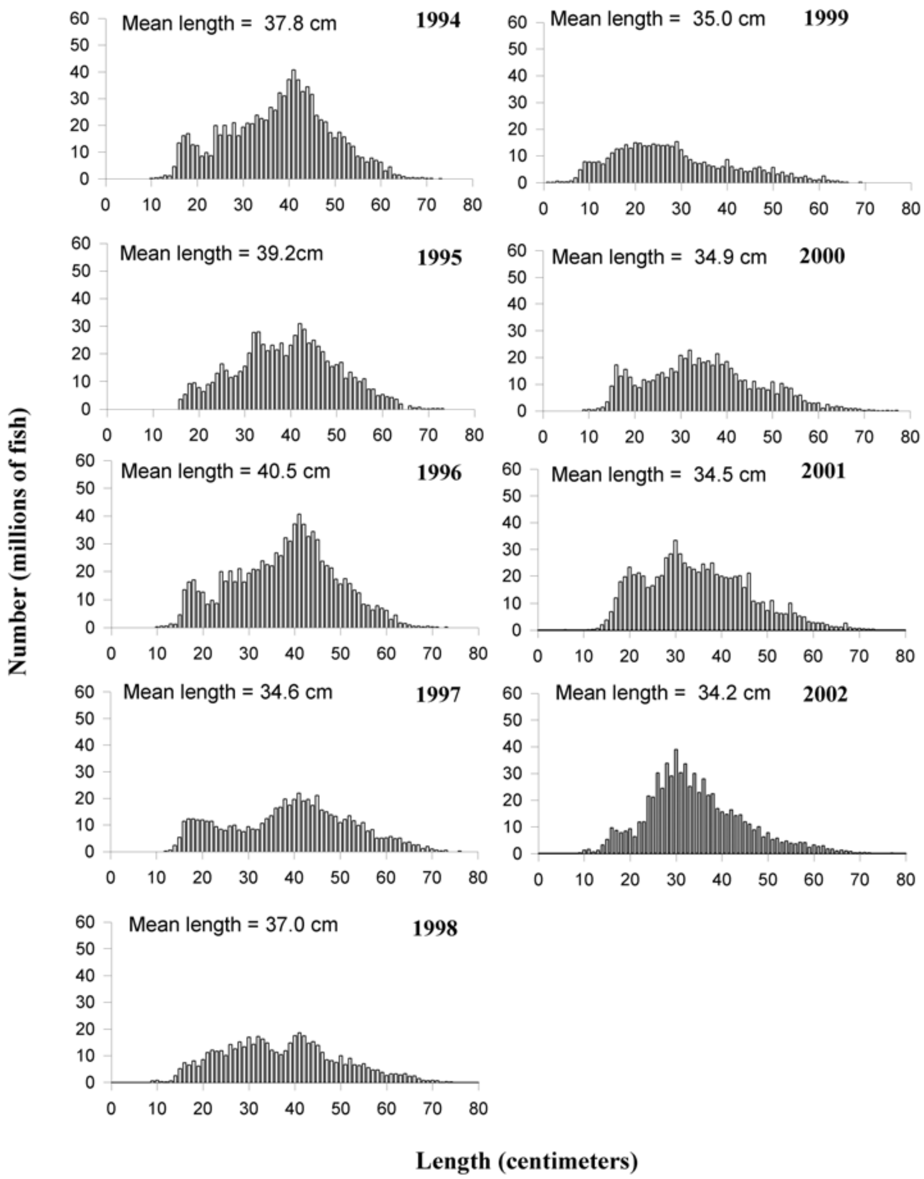


Figure 5.2-- Continued.

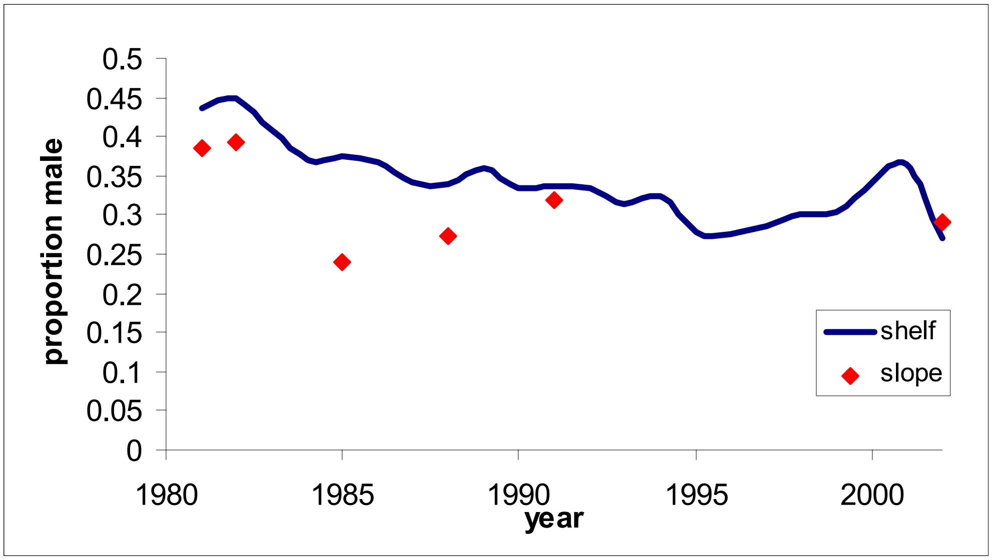
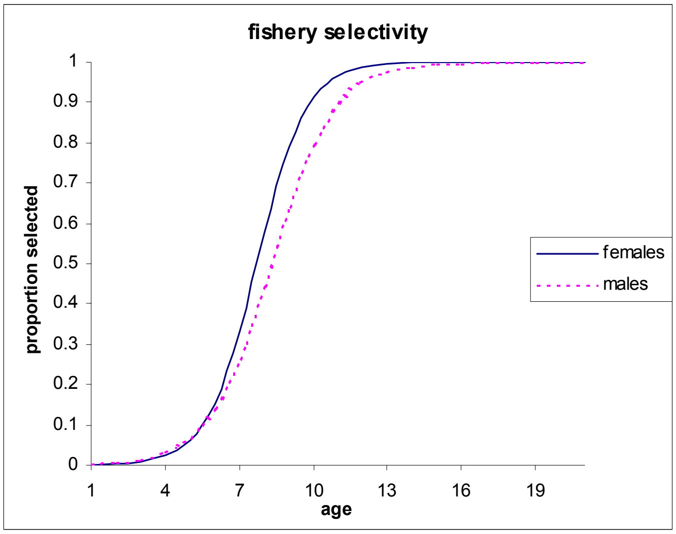
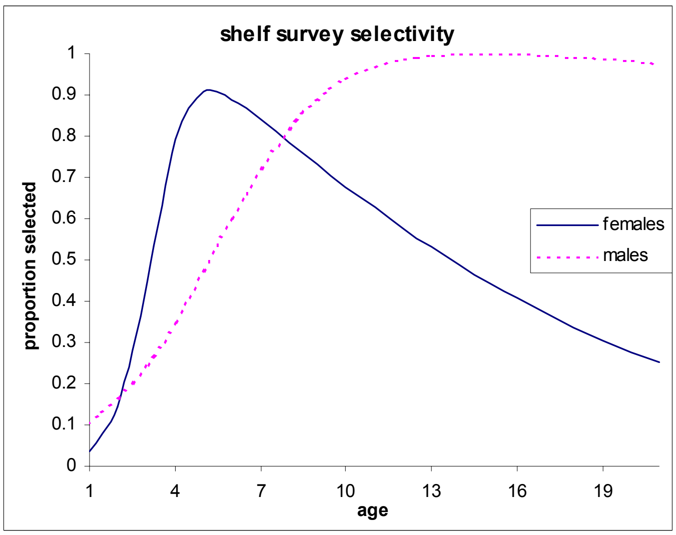


Figure 5.3--Proportion of the estimated male population from Bering Sea trawl surveys on the continental shelf and slope.





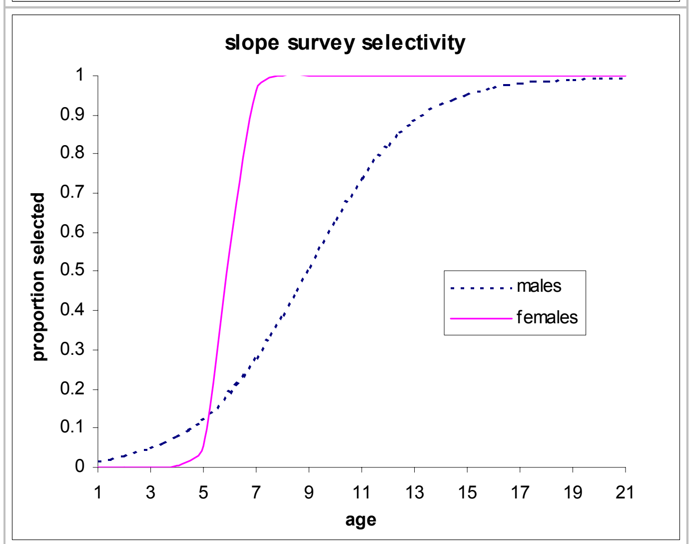


Figure 5.4--Age-specific fishery selectivity (top panel), shelf survey selectivity (middle panel) and slope survey selectivity (bottom panel), by sex, estimated from the stock assessment model.

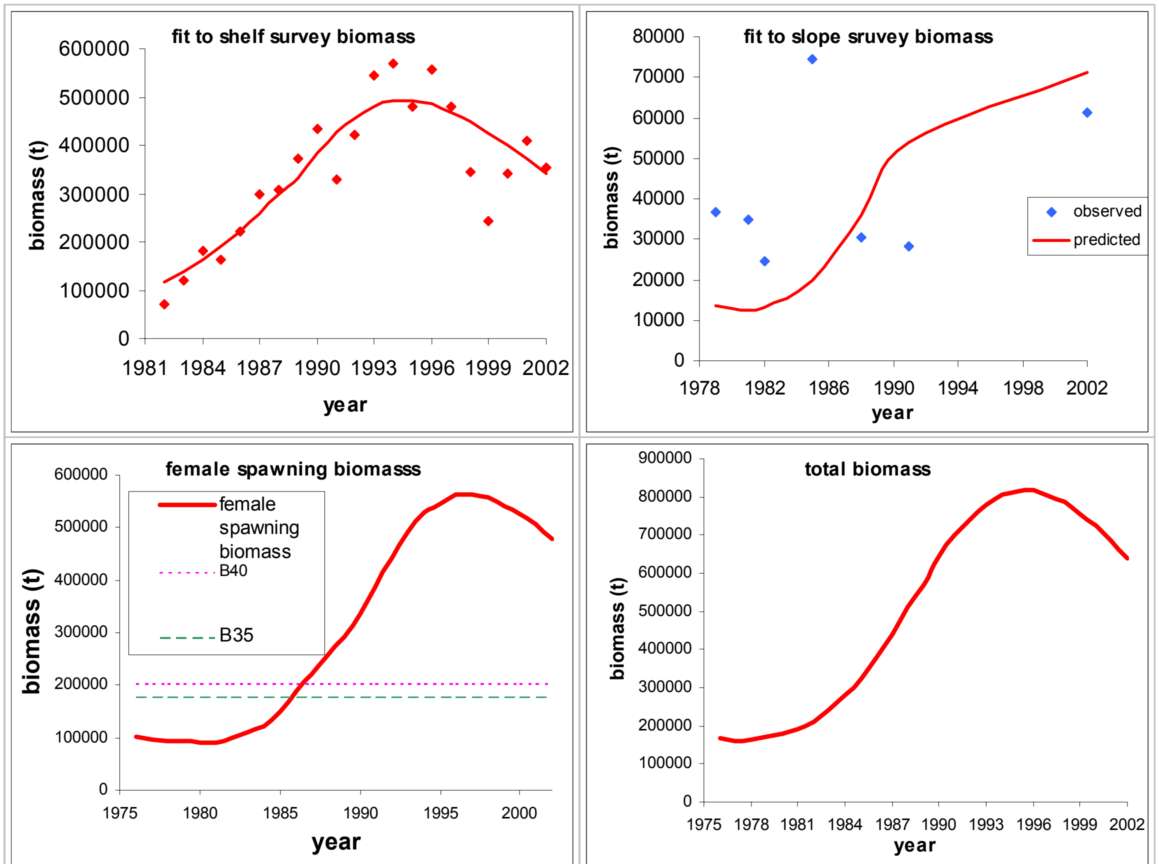


Figure 5.5--Stock assessment model results of the fit to the shelf survey biomass time-series (upper left panel), slope survey biomass (upper right panel), estimate of female spawning biomass with B_{35} and B_{40} indicated (bottom left panel) and the estimate of total biomass (bottom right panel).

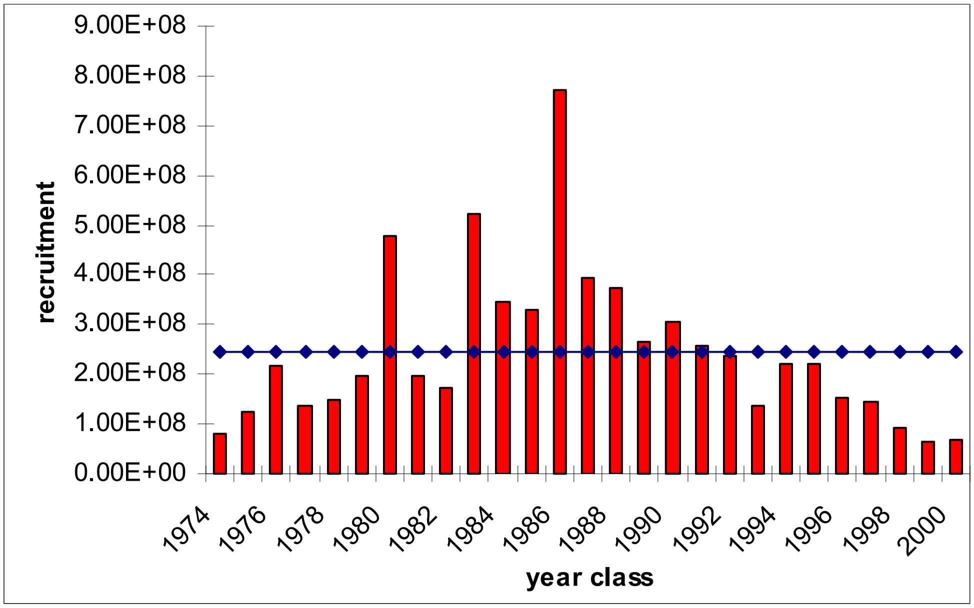


Figure 5.6--Estimates of arrowtooth flounder age 2 recruitment from the stock assessment model.

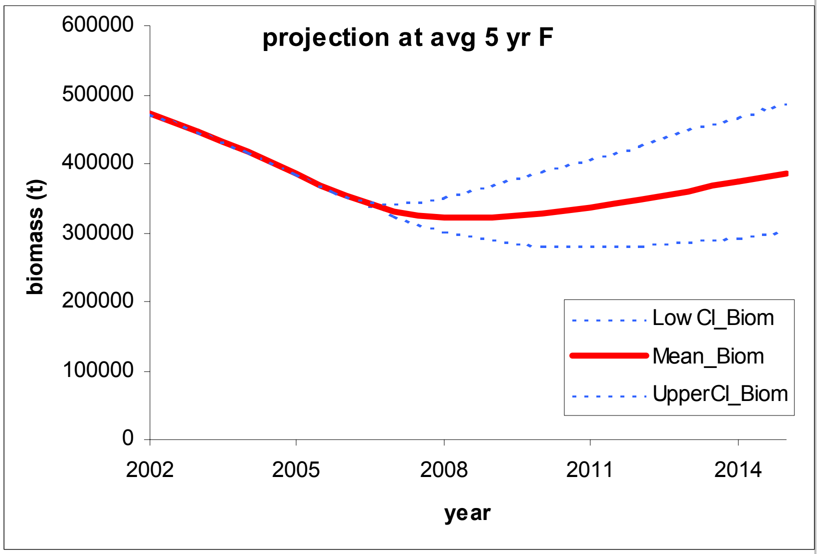


Figure 5.7--Projected female spawning biomass (t) of arrowtooth flounder if future harvest is at the same fishing mortality rate as the past five years.

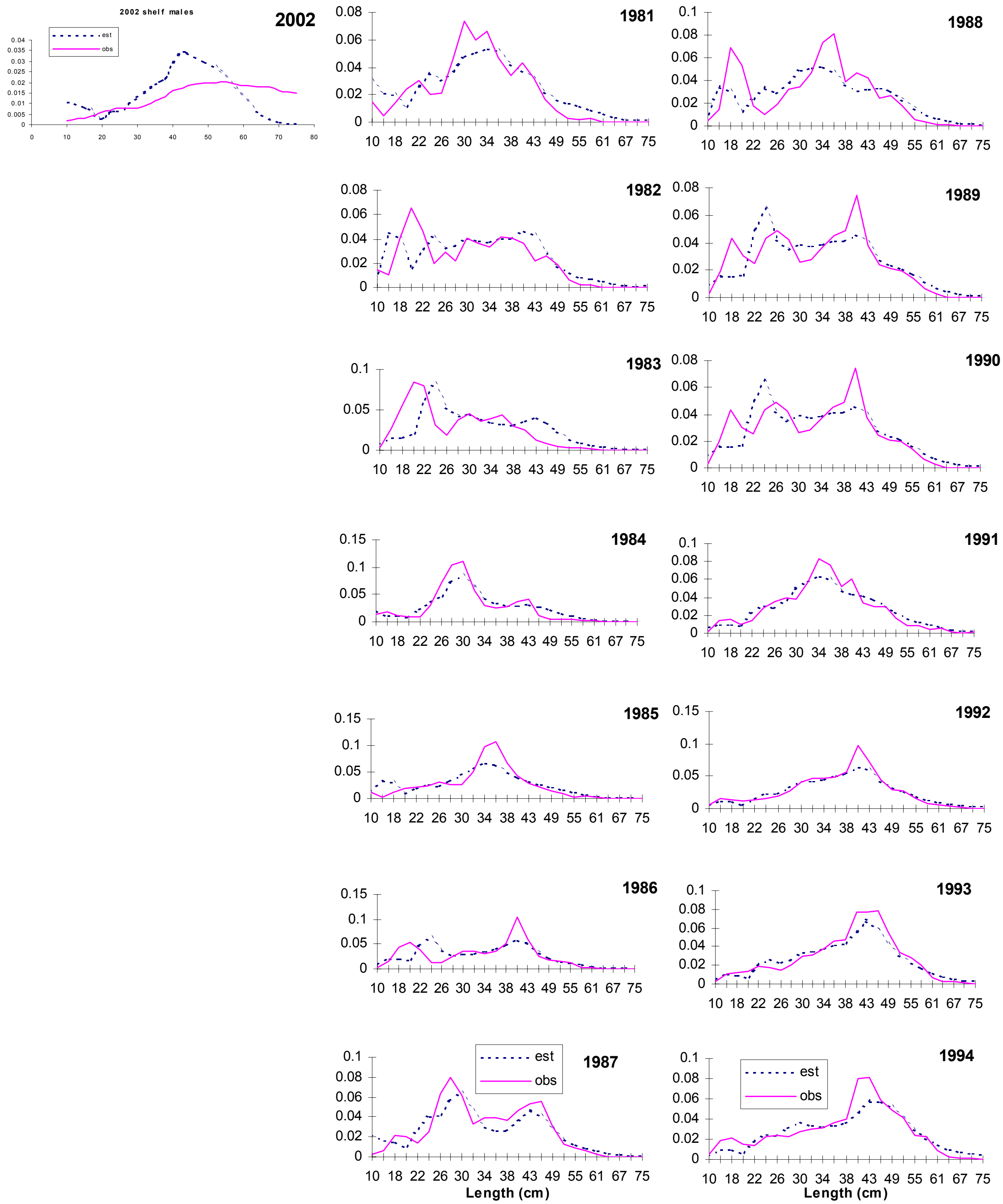
APPENDIX

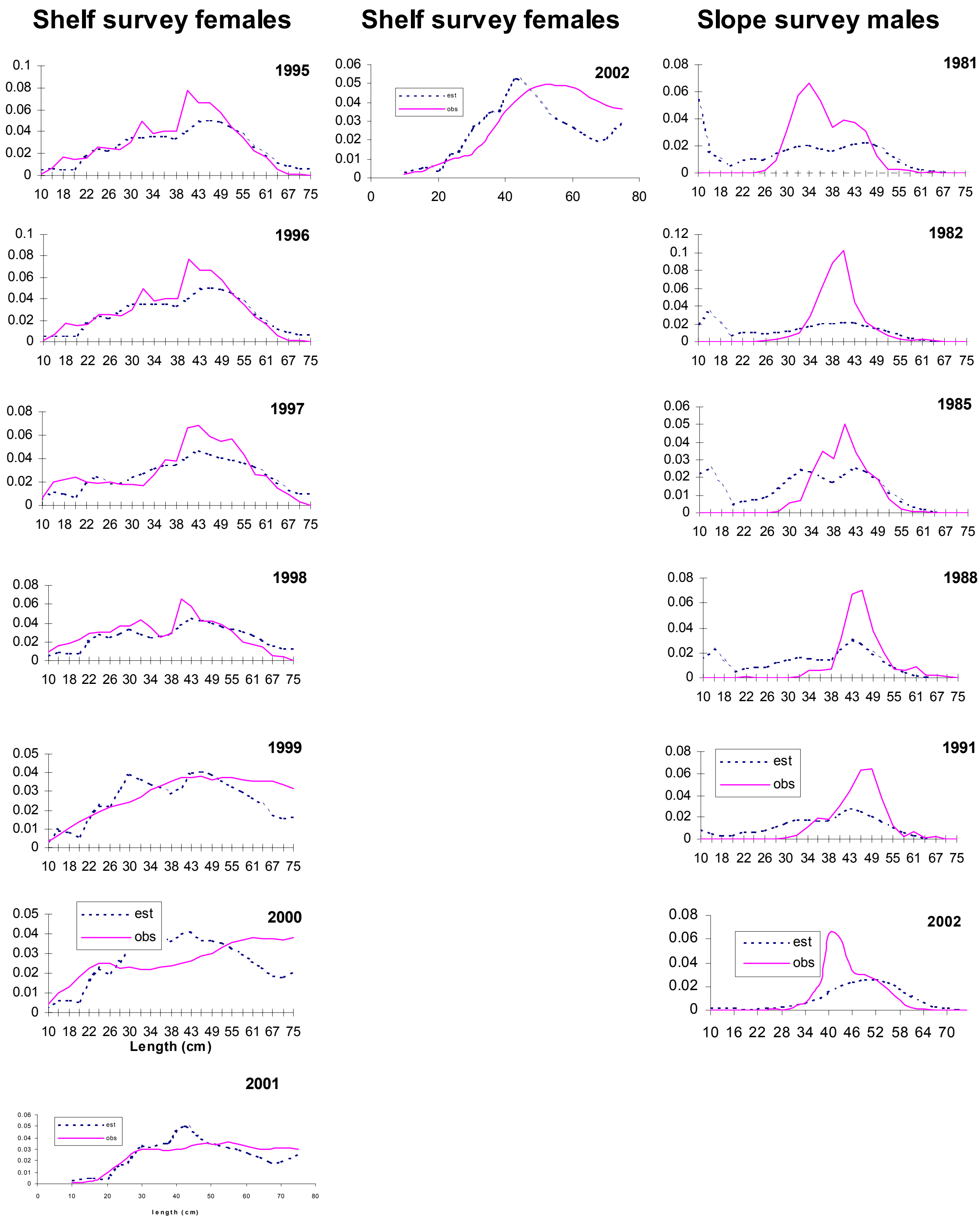
Figures show the fit of the stock assessment model to the time-series of shelf and slope survey size composition data by sex (estimated values are the dotted lines) and the fishery size composition data from 1978-90.

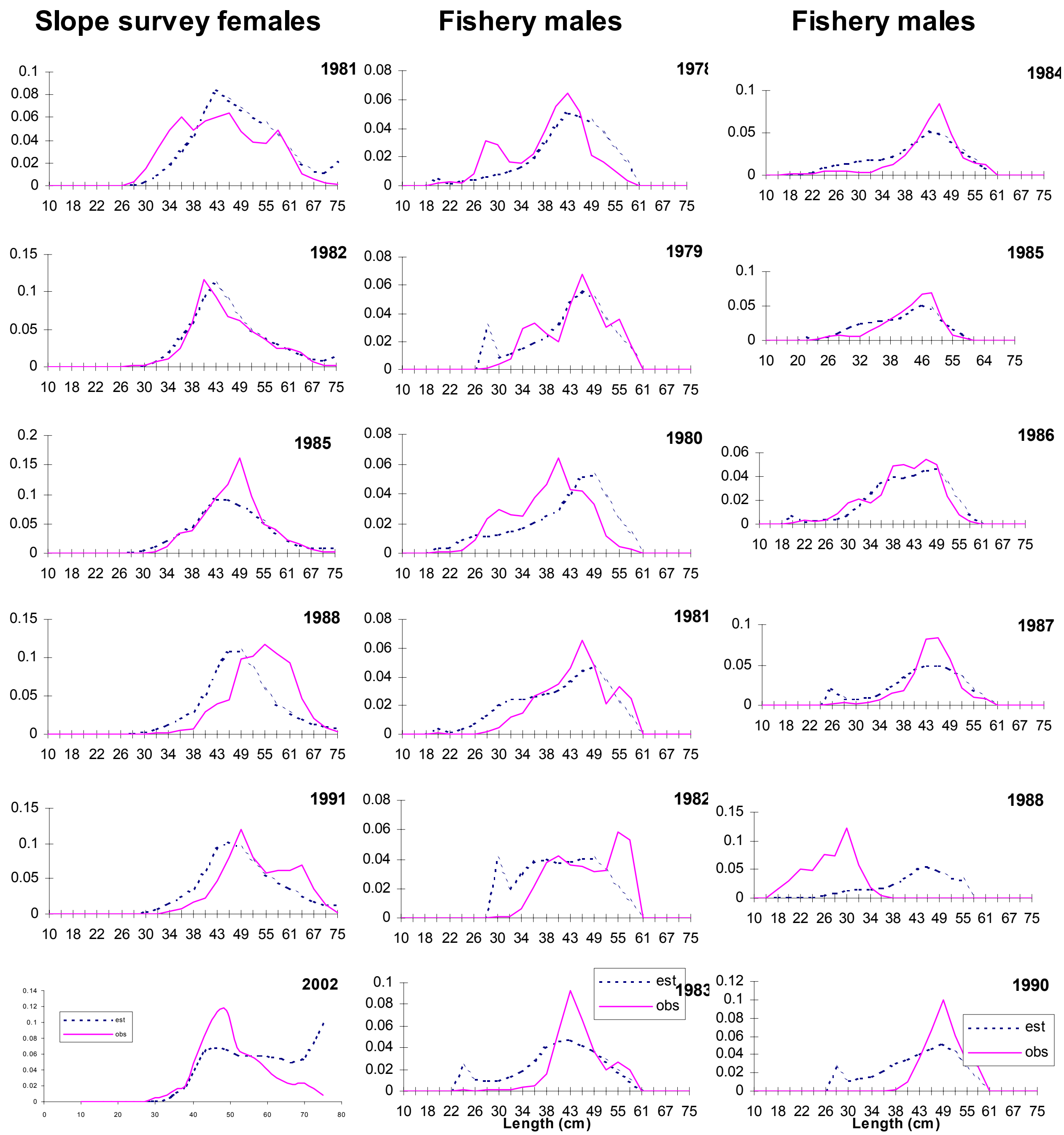
Table of arrowtooth flounder catch during research activities by the Alaska Fisheries Science Center, 1977-2002.

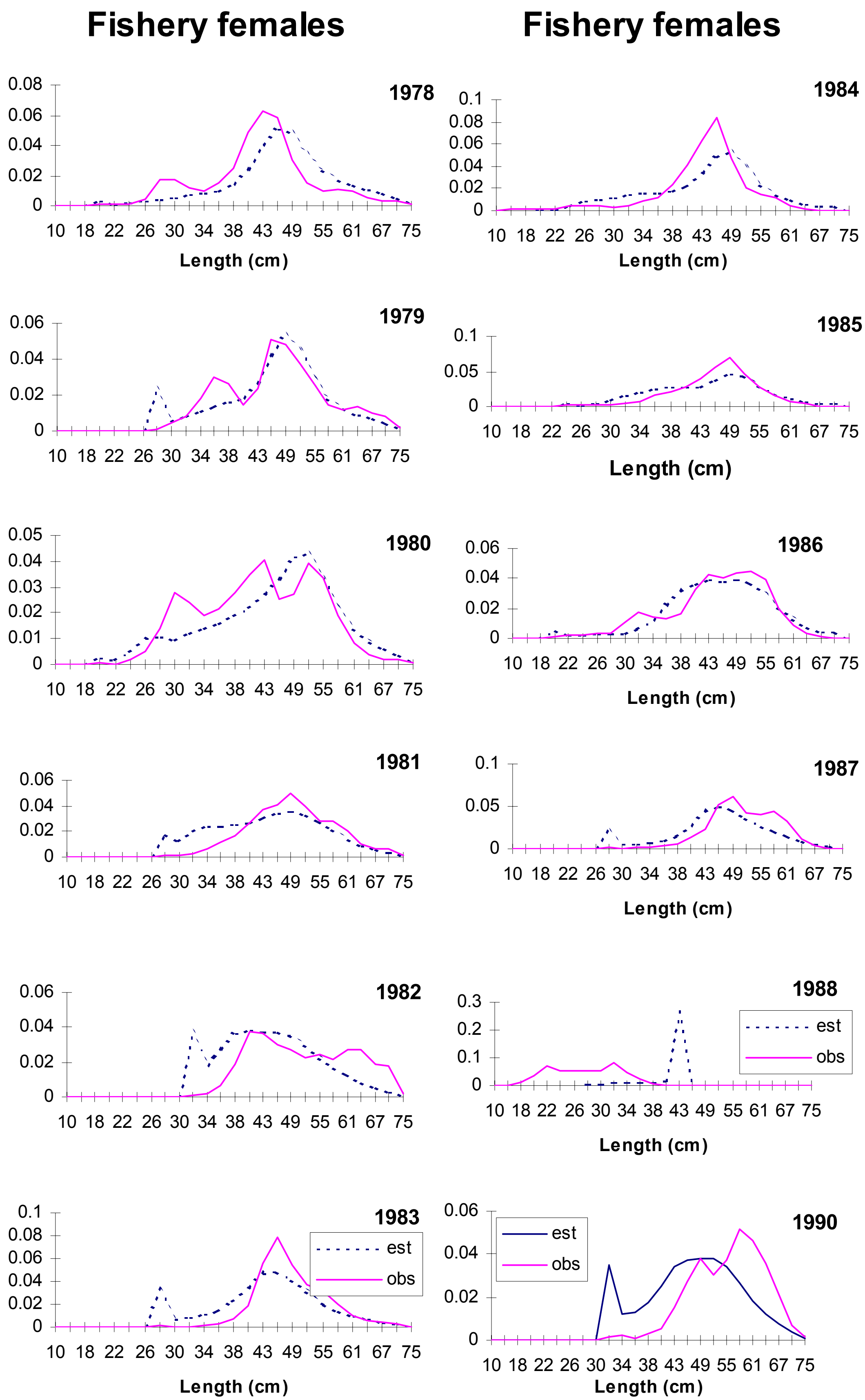

Shelf survey males
Shelf survey males
Shelf survey males
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
est
obs
est
obs
Length (cm)
Length cm)
length (cm)

Shelf survey males | Shelf survey females | Shelf survey females




Shelf survey females
Shelf survey females
Slope survey males
1995
1996
1997
1998
1999
2000
2001
2002
1981
1982
1985
1988
1991
2002
est
obs
Length (cm)
length (cm)


Slope survey females
Fishery males
Fishery males
1981
1982
1985
1988
1991
2002
1979
1980
1981
1982
1985
1986
1987
1988
1990
est
obs
Length (cm)
Length (cm)



Fishery females
Fishery females
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1990
Length (cm)
est
obs
10 18 22 26 30 34 38 43 49 55 61 67 75

Total catch (t) of arrowtooth flounder due to Alaska Fisheries Science Center research activity in the Bering Sea and Aleutian Islands, 1977-2000 and 2002.

year	Research catch (t)
1977	1.0
1978	3.7
1979	22.5
1980	63.6
1981	48.4
1982	46.6
1983	21.8
1984	6.1
1985	194.1
1986	57.7
1987	9.4
1988	33.7
1989	22.8
1990	18.4
1991	27.5
1992	10.9
1993	16.3
1994	40.7
1995	18.2
1996	17.9
1997	32.3
1998	12.6
1999	9.8
2000	10.8
2002	11.2